commercial buildings. Only in the extreme north of Alaska or Canada, due to the dark winter months, is there a lack of sufficient sunlight for daylighting purposes. The average illumination level under overcast skies at latitude of 50° is 7500 lux. This is about 15 times more illumination than that required to perform average indoor tasks.

Daylight in building design is recognized as a valuable means of improving energy effectiveness in commercial buildings. Refer to IESNA RP-5-99: *Daylighting Conference Proceedings,* May 1998. The research and design communities recognize it as a valuable way of providing tenants access to outside views. It has been identified in case studies and research that humans value their ability to maintain a visual link to the outside. This linkage re-enforces individuals with the sense of connectedness and comfort that the temporal and physical natural environment provides.

Daylight Design Criteria. Daylighting is essentially a systems integration challenge for a multi-disciplinary design team. It is important that daylighting considerations involve the participation and cooperation of the owner/tenant, architect, electrical lighting designer, mechanical systems engineer, interior designer, operation and maintenance staff and the construction team. Daylighting is unique in that it requires designers to address multi-disciplinary qualitative issues, in addition to the usual technical issues. For lighting to be truly effective, it must provide a comfortable and healthy visual environment that will support the activities of the occupants.

Even when excellent daylighting components or technologies are selected, poor integration can lead to unreliable building performance and uncomfortable work environments. Critical design elements include building orientation, fenestration size, lighting and control systems optimization and commissioning.

Daylight Design Concept and Integration Process. The daylight design process shall include the following steps;

- Concept, Design Basis
- Building Orientation and Form
- Daylighting the Perimeter
- Daylighting the Core
- Windows and Glazing identification and selection
- Shading, daylight controls and visual comfort
- Utilization of a Daylight Design Software, e.g. BDA
- Mechanical Coordination
- Auxiliary Lighting Integration
- Commissioning

Acoustics

The standards in this section have been established to ensure adequate acoustic qualities in Federal buildings.

Design Criteria for Building Spaces. Every element of a built space, including its shape, surfaces, furniture, light fixtures and mechanical systems contribute to its acoustical characteristics. Four key concepts govern the perceived quality of office acoustics:

- **Appropriate levels of speech privacy.** Speech privacy refers to the degree to which a conversation cannot be overheard in an adjacent space. Lawyers, doctors, human resources officers, executives and others whose position requires them to discuss sensitive information require confidential speech privacy, that is, a setting where, when a door is closed, the content of a conversation cannot be overheard. Professional staff members whose position requires extended periods of concentration require normal speech privacy, where the content of conversation in adjacent spaces cannot be overheard without making an effort, providing freedom from distraction. Little or no

speech privacy is needed for receptionists, clerical staff, and team-oriented workgroups where overheard conversation can actually be beneficial.

- **Appropriate levels of background sound.** Continuous background sound in offices is mostly generated by heating, ventilation, and air conditioning (HVAC) equipment. In conference spaces, courtrooms and auditoria, it is important that this background sound not interfere with the intelligibility of speech. In enclosed offices, HVAC background sound is an important component in achieving the required level of privacy because it helps to cover up or "mask" speech transmitted between adjacent spaces. In open plan areas, the background sound provided by contemporary HVAC equipment is often not uniform and/or does not have the tonal balance and loudness needed to mask speech transmitted between adjacent cubicles. For this reason, additional electronic background noise or sound masking is often deployed in these areas.
- **Control of intrusive noise, vibration, and reverberation.** Office equipment generating noise levels above the background should be located away from primary work areas or should be surrounded by acoustically isolating panels. Noise induced by mechanical equipment should be controlled through vibration isolation devices, appropriate placement of equipment and noise attenuators in ducts. Reverberation and echoes must be controlled in courtrooms, auditoria, conference, team, and training room spaces. Sound absorbing materials are used to help control reflected sound energy and echoes. Particular attention must be paid to rooms with parallel walls (causes "flutter" echoes) and rooms with curved or concave ceilings (leads to acoustical focusing effects).

Isolation from exterior noise sources. Buildings located near airports, highways, rail corridors or other sources of significant environmental noise levels must have exterior wall and window assemblies controlling noise intrusions.

Closed Offices Versus Open Plan. Required levels of acoustic privacy should be included as a design criterion. For work that does not require acoustic and/or visual privacy, an open plan environment with low or no partitions between workstations is appropriate. For work that requires a balance between ongoing, active collaboration, easy workgroup reconfiguration, flexible settings, and minimized unwanted acoustic distraction, an open plan setting with a well-engineered acoustical design is recommended. Key components of such engineered open plan designs are highly absorptive ceilings, suitable height partition panels that both absorb and block sound, suitable levels of background sound (typically provided by electronic sound masking systems), and ready access to acoustically private (closed office) meeting spaces. A protocol that encourages lowered voice levels is also recommended. Closed offices are encouraged for workers who routinely require extended periods of concentration, in-office meetings, and/or confidential conversation. Meeting spaces and closed offices that require speech security must be designed in conjunction with a qualified acoustical consultant.

Parameters Used in Acoustical Design. The following parameters are used to specify acoustical standards for GSA buildings:

Background Noise— the continuous noise within a space. The loudness of noise is quantified by several assessment schemes, including noise criteria (NC), balanced noise criteria (NC-B) and room criteria (RC) contours. These contours are published in the *ASHRAE Handbook of Fundamentals.* Lower values are quieter.

Environmental Noise— the continuous noise outside a building. The Day-Night Average Noise Level (DNL) is a descriptor established by the U.S. Environmental Protection Agency to describe the average day-night sound level. Lower values are quieter.

Noise Isolation— the amount of noise transmitted through the perimeter boundary elements of a space. *Sound transmission class* (STC) quantifies the sound insulating performance of building elements such as walls, windows, and doors when tested in a laboratory in accordance with ASTM E90. *Noise Isolation Class* (NIC) quantifies the field-tested sound isolation between two enclosed spaces separated by a partition when tested in accordance with ASTM E336. NIC accounts for both the sound insulating performance of the partition, and unintentional paths ("flanking paths") between the spaces (e.g. wall/ceiling connections, partition penetrations, etc.). The numerical value of NIC is usually less than that of the STC for the separating partition. NIC should only tested in fully furnished spaces. *Ceiling attenuation class* (CAC) quantifies the sound insulating performance of a ceiling assembly spanning across rooms that share a common plenum when tested in accordance with ASTM E1414. *Field Impact Insulation Class* (FIIC) quantifies the field-tested impact sound insulating properties of a floor/ceiling assembly when tested in accordance with ASTM E1007. Greater STC, NIC, CAC or FIIC values represent better performance.

Reverberation Time— the time required for sound to decay 60 decibels in the 500 Hz band in an enclosed space. Reverberation time becomes longer as the sound absorption is reduced and/or the room volume increases.

Sound Absorption— the amount of sound absorbed by a surface finish. *Sound absorption average* (SAA) quantifies the efficiency of a material in absorbing sound energy when tested in accordance with ASTM C423 (SAA replaces the earlier noise reduction coefficient or NRC). SAA/NRC is a single number rating between 0 and 1. Greater SAA/NRC values represent a more effective sound absorber. An excessive amount of reflected sound (reverberation) tends to degrade speech communication.

Speech Privacy— the amount of speech that can be understood in a space adjacent to the location where a conversation is occurring. Articulation Index (AI) is a measure of the intelligibility of speech, which is related to the level of the speech relative to the level of the background noise at a particular location. When tested in open plan offices in accordance with ASTM E1130, AI takes into account the noise reduction of partitions between spaces, the absorption in spaces, the distance between source (talker) and receiver (listener), the level of the background noise, and typical voice levels. AI is a single number rating between 0 and 1; lower AI values mean fewer words can be understood, indicating increased privacy. An AI value of .05 indicates less than 8% of speech in an adjacent space can be understood and is considered the upper threshold of "confidential" speech privacy. An AI of .15 means indicates that, with concentrated effort, nearly two-thirds of speech in an adjacent space can be understood. Recent research indicates that above this level, intruding conversation may become distracting. An AI of .20 is considered the upper threshold for "normal" speech privacy.

Design Criteria for Building Spaces. Acceptable acoustics are determined by the use of a space and the requirements of its occupants. It is the responsibility of the design team to meet the following minimum standards governing the acoustical performance of various space usage categories.

Environmental Noise. The impact of site noise on a building's interior spaces shall be mitigated under any of the following conditions:

- Building is located within an airport noise contour of DNL 60 or greater
- Building is located within 500 feet of a freeway or railroad right-of-way
- DNL at the building's property line exceeds 70 dB

Table 3-5

	1	2	3	4	5
Space	**Maximum Mechanical Noise (RC/NC)**	**Minimum Absorption: Ceiling (SAA/NRC)**	**Minimum Absorption: Walls (SAA/NRC)[1]**	**Minimum Noise Isolation (NIC)**	**Optimum Reverberation (RT60)**
Teleconference Facility	20	0.8/ 50%	0.8/ 25%	53	0.5
Meeting rooms, training facilities	25	0.8/ 50%	0.8/ 25%	48[2]	0.6
Private offices, confidential speech privacy	30	n/a	0.8/ 25%	45	n/a
Private offices, normal speech privacy	35	n/a	0.8/ 25%	40	n/a
Private offices, normal speech privacy, sound masking	35[3]	n/a	0.8/ 25%	35	n/a
Private offices, normal speech privacy, low voice level	35	n/a	0.8/ 25%	31	n/a
Open Plan offices, normal speech privacy, sound masking	40[4]	0.9/ 100%	0.8/ 25%	n/a	n/a
Open Plan offices, no speech privacy	40	0.8/ 100%	n/a	n/a	n/a
Child care center	35	0.8/ 80%	0.8/ 25%	31	0.5

[1] Absorption should be placed on two adjacent walls.

[2] Operable walls and partitions shall achieve the required NIC rating for the spaces that they are separating.

[3] Steady state background noise provided by electronic sound masking system: 40-42 dBA.

[4] Steady state background noise provided by electronic sound masking system: 45-8 dBA.

In such locations, an acoustical report shall be submitted showing that the building's acoustical design mitigates the intrusion of exterior noise to no more than 5 dBA over the maximum mechanical noise levels (Table 3-5, Column 1).

For locations where a railroad runs beneath or abuts the site, a newly constructed building shall contain provisions that minimize vibration transmitted to office spaces within the building, including feelable vibrations and vibrations in the form of audible noise.

Mechanical and Plumbing Noise. All mechanical equipment shall be vibration isolated per ASHRAE standards and guidelines, including spring isolators, inertia bases as well as ancillary items such as flexible piping and electrical connections. In seismic areas, acoustical vibration isolation must not compromise seismic code requirements and vice-versa. As such, housed springs should be avoided; instead, un-housed springs with separate seismic snubbers should be used.

Ambient noise from mechanical equipment shall not exceed noise criteria (NC) values shown in Table 3-5, Column 1, "*Mechanical Noise*". Diffusers with an NC rating 5 points less than the noise criterion for the space being served are required.

Where occupied space occurs adjacent to, above or below mechanical, electrical equipment, or machine rooms, or adjacent to HVAC or elevator shafts, the intervening structure (partitions, shaft walls, doors, floor and ceiling assemblies, etc.) shall be sufficient to control noise intrusion to no greater than the maximum noise criteria (NC) or room criteria (RC) values shown in Table 3-5, Column 1, "Mechanical Noise". Where an elevator shaft or equipment room occurs adjacent to noise sensitive spaces (NC/RC 35 or lower), the maximum intrusion level of elevator noise shall be limited to 5 dB below the maximum NC/RC for the space in all octave bands.

All hot-water heating, supply, waste, and drain piping shall be vibration isolated from the structure, as well as from other piping, ductwork, gypsum board, etc. in the walls, ceilings and floors enclosing noise sensitive spaces (Table 3-5, Column 2, NC/RC 35 or less). All stud and joist spaces where such piping is located shall have R-11 (3-½-inch thick) batt insulation installed, and piping shall not be closer than one-inch to gypsum board.

Noise isolation, room acoustics and speech privacy. Absorptive materials are required in speech sensitive spaces to control reverberation and echoes. Table 3-5, Columns 2 and 3 lists spaces that require absorptive finishes. The first number in each column refers to the minimum level of the material's performance; the second refers to the minimum percentage of the ceiling or wall that must have finishes achieving this performance.

Floor/Ceiling assemblies separating office spaces shall achieve an NIC of not less than 50 (when furnished) and Field Impact Isolation Class (FIIC) of not less than 50. Table 3-5, Column 4 lists the minimum noise isolation (NIC) for spaces requiring acoustically rated walls.

For constructions on suitable slab floors, when properly detailed and constructed, and with all connections caulked airtight with acoustical sealant, the following wall assemblies will satisfy the minimum specified NIC requirements, with the offices furnished typically. Doors and other holes in the walls will degrade the overall performance. These wall examples are not the only constructions that will satisfy the performance criteria, but are intended solely to provide guidance on projects that do not require a qualified acoustical consultant during the design phase.

U.S. Courthouse at Foley Square, New York, NY

NIC 53 (teleconference room): double stud wall, two layers of gypsum board each side, batt insulation in the stud cavities. Full height (slab to slab).

NIC 48 (meeting rooms, training facilities): staggered stud wall, two layers of gypsum board each side, batt insulation in the stud cavity. Full height (slab to slab).

NIC 45 (private offices, confidential speech privacy): single stud wall, two layers of gypsum board each side, batt insulation in the stud cavity. Full height (slab to slab) or six-inches above a hung gypsum board ceiling.

NIC 40 (private offices, normal speech privacy): single stud wall, two layers of gypsum board one side, one layer of gypsum board the other side, batt insulation in stud cavity. Slab to slab (preferred); minimum six-inches above acoustical tile ceiling (minimum CAC 44).

NIC 35 (private offices, normal speech privacy, sound masking): single stud wall, single layer gypsum board each side, batt insulation in stud cavity. Minimum six-inches above acoustical tile ceiling (minimum CAC 44).

NIC 31 (private offices, normal speech privacy, low voice level; misc. other spaces): single stud wall, single layer of gypsum board each side, batt insulation in the stud cavity. Terminates at underside of acoustical tile ceiling (minimum CAC 35).

Commissioning. Verification that the above acoustical requirements have been met is required as part of contract documents. Acceptable documentation includes either a report by an acoustical engineer, stating that the intent of these requirements has been met, or other documentation showing that these acoustical requirements have been incorporated as contractual requirements. Contracting Officer may require, at no cost to the Government, test reports by a qualified acoustical consultant showing that acoustical requirements have been met by as-built construction.